THE EFFECT'S OF CHANGING THE UNIFORM BUILDING CODE SEISMIC ZONE FROM ZONE 3 TO ZONE 4 ON THE WASATCH FRONT OF UTAH (BRIGHAM CITY TO NEPHI)

FINAL REPORT

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PREFACE

The National Earthquake Hazard Reduction Act, passed by congress in 1977, created the National Earthquake Hazard Reduction Program (NEHRP). The Federal Emergency Management Agency (FEMA), U.S. Geological Survey, National Institute of Standards and Technology, and the National Science Foundation administer the NEHRP with FEMA being the lead agency. Of the fifty states, forty-one have some earthquake-related hazard and potential for damage due to earthquake. FEMA cooperates with these states to implement earthquake hazard and risk reduction projects.

This publication represents a joint project between FEMA and the State of Utah through the Utah Division of Emergency Services and Homeland Security's Earthquake Preparedness Information Center (EPICENTER). The Utah Division of Emergency Services and Homeland Security (DES): Lorayne Frank, DES Director; Fred May, Natural Hazards Program Manager; Bob Carey, EPICENTER Manager; Caryn Johnson, Natural Hazards Intern. Jim Tingey was instrumental in initiating this project.

DISCLAIMER

This publication was prepared as an objective assessment of the consequences of changing the Uniform Building Code Seismic Zone from zone 3 to zone 4 on the Wasatch Front of Utah (Brigham City to Nephi). The agencies and businesses involved in preparation of this publication assume no responsibility for any action taken based on information found in this publication.

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1.0 INTRODUCTION, SCOPE AND CONTENT

1.1 Introduction

On July 8, 1991, after extensive discussions and a public hearing, the Uniform Building Code Commission of the State of Utah filed a code change submittal' with the International Conference of Building Officials (ICBO) to change the Uniform Building Code Seismic Zone from Zone 3 to Zone 4 along the Wasatch Front of Utah (Brigham City to Nephi). The area affected by this proposed change, along with the seismic zonation for Utah as a whole is shown in Figure 1, adapted from the zone change submittal. The current seismic zonation for Utah, as well as the United States, is shown in Figure 2.

There are six seismic zones within the Uniform Building Code: 0, 1, 2A, 2B, 3, and 4. Zone 0 represents minimum seismic risk with higher numbers representing increasing risk up to Zone 4, the maximum seismic risk zone. Zone 2 is subdivided into two zones, 2A and 2B. At present, the central Wasatch Front area of Utah is classified as Zone 3. Western Utah and south-central Utah is Zone 2B; eastern Utah is Zone 1.

Uniform Building Code Seismic Zones are based on the probability of expected intensity of ground shaking from earthquakes. Specifically, the zones are based on expected effective peak accelerations on rock with a 10 percent chance of being exceeded in 50 years. Seismic Zones 3 and 4 correspond to regions where expected peak accelerations (as a fraction of the acceleration of gravity, g) are between 0.2 and 0.3 g (Zone 3) or greater than 0.3 g (Zone 4). Expected peak accelerations at a given location are not known exactly, but rather are estimated from seismological studies.

The reason for the code change submittal was stated as:

> "Under the auspices of the National Earthquake Hazard Reduction Program (NEHRP), extensive research on earthquake sources and hazards along the Wasatch Front was conducted in the past ten years. Much of the knowledge gained was incorporated into a 1987 probabilistic ground shaking analysis that indicates larger peak ground accelerations than were mapped in previous studies that were the basis of the 1988 Seismic Zone Map. These new estimates of accelerations,

with a 10 percent probability of being exceeded in 50 years, range from 0.3 g to 0.4 g along the central Wasatch Front. By definition, (SEAOC Blue Book) this meets the criteria for seismic zone 4.'"

Following normal ICBO code change submittal procedure,' the zone change submittal was processed by staff and published in Part III of Building Standards' magazine. In cases where the effect of a proposal is not obvious, a staff analysis of the proposal is developed for publication with the proposal. In this case, no analysis was performed. Code change submittals are reviewed by six ICBO committees. Seismic zonation issues are handled by the Lateral Design Committee. Testimony for and against this code change submittal was heard at the Committee meeting in February, 1992 in Indianapolis. The Committee disapproved the code change submittal; the formal reason for this disapproval was stated in the 1992 Annual Report of the Code Development Committees as: "There was not enough data to support a change in seismic zone." After this disapproval, proponents chose not to pursue a challenge. Therefore, the submittal was not taken to the annual meeting for a formal vote by ICBO voting members and the code change submittal expired.

Formally, ICBO Code Development Committees evaluate code change submittals on the technical merits of the submittal. However, the Lateral Design Committee, which evaluates seismic zone changes, does not consist of technical experts specializing in expected seismic ground motions. Furthermore, ICBO rarely, if ever, approves a seismic zone increase without a strong consensus from the building officials in the region affected by the zone change. Therefore, the Committee's disapproval of the seismic zone change submittal predominantly reflects and acknowledges the marked lack of consensus within Utah about the merits of the zone change. Despite the formal reason given for disapproval ("not enough data"), the Committee disapproval should not be interpreted as a technical consensus about the merits of the zone change with respect to the seismic zone criteria established by ICBO.

1.2 Scope and Content of this Assessment

The purpose of this assessment is to investigate the expected socioeconomic impacts if the Uniform Building Code Seismic Zone were changed from Zone 3 to Zone 4 along the Wasatch Front of Utah. This report is intended to be a primer for interested citizens who are concerned about the possible impacts of such a Seismic Zone change. An evaluation of whether or not the technical basis for seismic risk along the Wasatch Front of Utah meets the established ICBO criteria for Seismic Zone 4 is not within the scope of this assessment.

Chapter I provides a brief introduction to seismic zone changes and an overview of the scope and content of this assessment.

Chapter 2 provides background and context information to assist the reader in;.-. understanding the more technical discussions about impacts of a building code seismic zone change which follow. Chapter 2 also contains a brief review of the intent and purpose of building codes, a review of the seismic risk along the Wasatch Front, and a summary of the expected impacts of a major earthquake along the Wasatch Front.

Chapter 3 provides assessments of the socioeconomic consequences of a prospective change in the UBC Seismic Zone from Zone 3 to Zone 4. This chapter provides answers to frequently asked questions about the possible impacts of such a zone change.

Chapter 4 provides a summary and overview of the socioeconomic impacts of the prospective UBC Seismic Zone change.

1.3 Seismic Risk and Socio-Economic Impacts of Code Changes

In evaluating the expected socioeconomic impacts of a Seismic Zone change, it is extremely important to separate the possible impacts of the Seismic Zone change from those negative impacts which arise because of the seismic risk itself. All other factors being equal, very few cities would choose (if given the choice) to have active earthquake faults affecting their populations. Clearly, as well-documented from numerous earthquakes worldwide, a major earthquake in an urban area may cause extreme property damage and many casualties.

A Seismic Zone change is not the sole originator of negative socioeconomic impacts of seismic risk. The socioeconomic impacts which arise from a city being at seismic risk may be considered in three main categories:

- OBJECTIVE SEISMIC RISK,
- PERCEIVED SEISMIC RISK, and
- BUILDING CODE SEISMIC ZONE.

Objective seismic risk is based on the analysis of physical data: geological, seismological, geotechnical and engineering. The expected occurrence of future earthquakes in a given location can be estimated only probabilistically and different seismologists may make different interpretations of the same available data. Nevertheless, there is generally a reasonable degree of consensus in the professional community about the approximate level of seismic risk faced by a given city. Objective seismic risk may have significant negative socioeconomic impacts on a community. Negative impacts may include increased building costs compared to lower risk locations and risk-based decisions by people or businesses to locate (or relocate) elsewhere. However, the negative impacts of objective seismic risk may be substantially reduced by public education, risk-reduction actions (including Building Codes), and increased preparedness.

Perceived seismic risk may also have negative impacts on a community. Fear of earthquakes (real or not) may affect decisions by people or businesses. However, for the preponderant majority of citizens, earthquake risk (perceived or objective) has a very low priority compared to other factors (weather, location, cultural amenities, business opportunities) which govern personal or business decisions. Even in high seismic risk cities, many people remain virtually oblivious to seismic risk. People who are fully informed and knowledgeable about seismic risk may deny the objective risk and pursue their personal or business activities without consideration of seismic risk. Furthermore, perceived risk may have positive impacts if the perceived risk results in greater public education, risk-reduction actions, and increased preparedness.

Building Code Seismic Zone decisions may also have socioeconomic impacts on a city. 'Me effects of Seismic Zone classifications are, however, generally small compared to the impacts of objective or perceived seismic risk. Furthermore, the socioeconomic impacts of Seismic

Zone classifications may be both positive and negative. Positive impacts (benefits) of an objectively determined Seismic Zone classification are generated because new buildings built to code standards are expected to perform better in future earthquakes with less property damage, less disruption of business functions and fewer casualties. The knowledge that new buildings are built to be seismically resistant may substantially offset the negative impacts which may accrue from objective or perceived seismic risk. If the Building Code Seismic Zone is commensurate with the objective seismic risk, then the benefits may be expected to exceed the costs. If, however, the Building Seismic Zone is set either too high or too low, relative to the objective seismic risks, then the costs will exceed the benefits of the code. If the Seismic Zone is set too high, then the benefits of better buildings will not suffice to offset the greater costs. On the other hand, if the Seismic Zone is set too low, then the cost savings will not suffice to offset the greater damage, losses, and casualties that will eventually result from future earthquakes. Clearly, establishing a Building Code Seismic Zone which is commensurate with the objective seismic risk is a desirable objective.

2.0 BACKGROUND AND CONTEXT

2.1 Overview of the Uniform Building Code

This section summarizes the purpose of the-Uniform Building Code and briefly reviews how its requirements are developed and changed.

The Uniform Building Code (UBC) is one of three major model codes used by local and state jurisdictions throughout the United States to regulate construction of buildings. The UBC is most commonly used in the western and Midwestern regions of the country, including the State of Utah. The UBC is a consensus-based document that is updated annually and published every third year by the International Conference of Building Officials (ICBO). The principal issues that the building code addresses in its regulations are those of fire resistivity, occupant safety and structural adequacy. The regulation of the electrical, plumbing, and mechanical components of buildings are contained in separate, closely-related, companion codes.

The code's principal purpose as stated in its Administrative Chapter is:

> "...to provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of buildings..." (emphasis added).

For the Uniform Building Code to be effective in meeting this purpose it must be adopted as law and enforced through effective administration by a city, county or state government. During their adoption process these jurisdictions may decide to modify certain code requirements to address unique local conditions that the model code did not consider as common or universally necessary. These changes are-e in most cases more restrictive than those found in the standard code provisions and hence enhance the level of safety provided.

The first edition of the UBC was published in 1927-and has evolved over the past six decades to incorporate new construction methods and materials, new scientific concepts for structural design and to meet the challenges of providing a safe environment for building occupants in a complex modem world. Careful consideration of those new concepts, methods and materials based on rigorous research, testing and documentation prior to their acceptance has led to a code that balances the costs of personal safety and property protection with the benefits that the public has come to expect.

In jurisdictions where the UBC is formally adopted, architects and engineers are legally required to comply with the minimum standards established in the code. However, due to economic considerations, these minimum standards established by the code most often translate into the maximum standards used in design and construction practice. Therefore, establishing realistic minimum standards in the code is of paramount importance because they normally become the actual maximum level of safety provided in most buildings.

Changes to the UBC can be proposed by any interested person but are normally suggested by groups of building officials who enforce the code, or by associations representing design professionals and other construction industry associations who use the code. The process for a proposed change to become part of the code is arduous and filled with opportunities for review and challenge of the proposal; reference 2 provides full details of the code change process. As a result of this careful, deliberative code change process, some proposed changes may take as much as 10 years to successfully complete the process of review, approval, publication, adoption, and enforcement.

The component of the Uniform Building Code's structural design requirements of primary interest in this report is the choice of seismic zone for a given location. The map contained in the UBC that locates the boundaries of six seismic zones occurring in the United States is founded on scientific studies of the intensity of ground motion and damage patterns produced in past earthquakes and the location of the fault zones where these earthquakes have occurred. The basis for this map as well as other seismic design requirements in the UBC are subject to review and periodic change as better information on these subjects becomes available.

The seismic zone boundaries in the western U.S. have been revised twice since the 1979 edition of the UBC. Substantial changes in the zone boundaries took place in the 1988 edition based primarily on the mapping prepared as a result of research conducted by the National Earthquake Hazards Reduction Program. The purpose of these changes was to provide a more accurate basis for successfully meeting the basic intent of the code. An additional seismic zone change, affecting southern Arizona, was approved in 1992.

For a building to successfully meet the intent of the UBC's dual purposes of protecting life and property it must be able to sustain the maximum earthquake forces expected to occur during its life span without collapse, and also be able to resist moderate but more frequent earthquakes with only minor repairable damage. One of the primary parameters contained in the code to accomplish this goal is -the determination of the appropriate seismic zone. As new scientific knowledge accumulates on the potential for damaging earthquakes in various locations throughout the country, appropriate changes to the seismic zone map must continue to be made to maintain the level of safety intended by the code.

2.2 Seismic Risk Along the Wasatch Front

The Utah Geological Survey recently reviewed earthquake risk in Utah.' The University of Utah Seismological Station records about 700 earthquakes per year in Utah, of which an average of 13 are of magnitude 3.0 or greater. On average, a moderate potentially-damaging earthquake (magnitude 5.5 to 6.5) occurs someplace in Utah about once every 7 years. The two largest historical earthquakes in Utah took place near Richfield in 1901 and in Hansel Valley in 1934, with magnitudes of about 6.5 and 6.6, respectively.

The largest earthquakes in Utah are likely to occur in the Intermountain Seismic Belt, a zone of active seismicity which extends in a north-south direction about 800 miles from Montana to northern Arizona. Since 1850, there have been at least 16 moderate to large earthquakes (magnitude 6.0 or greater) along this belt. In Utah, the Intermountain Seismic Belt trends from the Tremonton-Cache Valley area, through the center of the state along the Wasatch Front, and then southwest through Richfield and Cedar City. The 1991 Uniform Building Code seismic zone along the northern Intermountain Seismic Belt is Zone 4 in a small oval area including portions of Idaho, Montana, and Wyoming. The seismic zone is Zone 3 along the rest of the Seismic Belt through Montana, Idaho, Wyoming and north central Utah.

Along the Wasatch Front (Brigham City to Nephi), seismic risk is due to the Wasatch Fault system and to numerous other faults, several of which run directly through highly populated areas. The Wasatch Fault, which runs along the western edge of the Wasatch Mountains, consists of 10 segments, each 12 to 44 miles long, which generally act independently and rupture during separate earthquakes. Geologic studies indicate that the fault segments between Brigham City and Nephi have an average time interval between large earthquakes of approximately 395 + 60 years. The most recent major earthquake on the Wasatch Fault occurred about 400 years ago on the Nephi segment.

The severity of the impact of an earthquake on a community depends on the intensity and duration of ground shaking and on the occurrence of other seismically-induced phenomena such as surface rupture, subsidence, soil liquefaction, and slope failures. In addition, major earthquakes can cause several other types of damaging phenomena, including flooding from tilting lake beds, dam failures, seiches (waves in standing bodies of water), and disruption of surface drainage. The severity of such possible impacts of an earthquake depends on the magnitude of the event, the distance between the community and the fault, and on local geologic conditions such as susceptibility of soils to liquefaction or amplification of ground motions.

2.3 Expected Impacts of a Major Earthquake Along the Wasatch Front

Seismic risk along the Wasatch Front is particularly important from a public policy perspective because more than 85% of Utah's population is concentrated there, along with many critical facilities (dams, utility lifelines, and others), government centers and major industries. There will be severe impacts to the cities along the Wasatch Front when a moderate to major earthquake occurs. Planning studies conducted by the United States Geological Survey' and by the State of Utah" of the expected physical and socioeconomic impacts of major earthquakes on the Salt Lake City area graphically illustrate the awesome destructive power of earthquakes.

The most recent United States Geological Survey earthquake damage estimates' for the Wasatch Front region considered earthquakes of magnitudes 7.5, 6.5 and 5.5. An earthquake of magnitude 7.5 is considered the maximum probable earthquake in this region. Including earthquakes as large as magnitude 7.5 in the planning scenarios is based on historical seismicity within the Wasatch Front region, elsewhere along the Inter-mountain Seismic Belt, and within the Basin and Range region's Large earthquakes in this area, with magnitudes of 6.9 to 7.5, had fault ruptures averaging about 20 miles in length. Therefore, based on fault segment lengths along the Wasatch Front and on the other faults in the area, earthquakes as large as magnitude 7.5 are possible along the Wasatch Front.

The scenario impacts summarized below are estimates which are based on the references cited above.' Such estimates may only approximately indicate the actual levels of damages and socioeconomic impacts which would occur in a future earthquake. Nevertheless, the severity of these scenario impact estimates dramatically emphasizes the importance of dealing with the earthquake threat along the Wasatch Front in an informed and realistic manner.

2.3.1 Physical Effects

Expected seismic damage to the area results from several factors. The most important of these is groundshaking because it effects the widest area, will produce the most damage to buildings, and may trigger other hazards, such as landslides. Strong shaking might last 10 to 30 seconds or more and could produce significant damage up to 60 miles away. A major earthquake could result in vertical scarps as much as 10 to 18 feet high, and surface rupturing in segments 12 to 44 miles long. Such surface faulting destroys buildings astride the fault and severely damages utilities and transportation facilities that cross the fault, malting them unusable for weeks, months or years.

Liquefaction, the loss of strength in saturated and sandy soils subject to earthquake shaking, will almost certainly play a major role in damage because of the high ground water level and the amount of residential, industrial, and commercial development along the lower lying areas. Utilities and transportation routes are likely to be severely damaged, buildings could tip or settle into the soft materials, and lighter weight structures, such as buried tanks, could "float" to the surface. Foundations may be damaged, buildings could be flooded, and, because of the changes in the slope, gravity-fed pipelines could back up. Older dams with liquefiable foundation materials in the upper canyon areas could also fail.

A large earthquake could generate several thousand rock falls along the mountain front, in the canyons, and up to 175 miles away in steep slope areas. Landslides and land flows would also be common, especially if the slopes are wet. When snow is present, avalanches can be expected in the Wasatch Range from the earthquake's shaking.

Flooding could have major impacts on the area. The most serious would be dam failures, but others could result from subsidence (the dropping in elevation of portions of the area due to the settlement of the soils), or in this case the tilting downward of the western land block along the fault. This could result in inundation of areas as far into Salt Lake City as State Street (100 East). Seiches (damaging waves produced by shaking in enclosed lakes and reservoirs) could also result in additional damage and loss of life. Local ground water discharges could also add to the flood damages.

2.3.2 Socio-Economic Impacts

Moderate to large earthquakes along the Wasatch Front will damage property (buildings and infrastructure) and cause casualties (deaths and injuries). The extent of property damage and casualties depends on the magnitude and location of the earthquake. The expected socioeconomic impacts summarized below are "scenario" estimates made by informed experts in these fields.' In detail, these estimates may or may not be accurate in predicting the exact impacts of future earthquakes. Such scenario estimates do, however, illustrate the approximate level of casualties, damages and disruptions which are expected.

Estimated damages to buildings in Utah (based on reconstruction costs) range from about $830 million from a moderate 5.5 magnitude earthquake on the Provo segment, to about $2.3 billion from a 6.5 magnitude event, and about $10 billion from a 7.0 - 7.5 magnitude major earthquake along the Salt Lake segment. Two factors help explain these high losses: (1) the high number of unreinforced brick houses (which do not perform well in earthquakes) in the area, and (2) the proximity of major population centers to the faults and the strong ground motions associated with the soils and surface materials along the front. After a major earthquake, aftershocks are likely and will add to the damages in the area.

The "worst case scenario" is a magnitude 7.5 earthquake in Salt Lake County. Such an earthquake would have devastating effects in the immediate area and to the north in Davis and Weber counties and in Utah County to the south. Serious effects could also occur in locations to the east and west. This earthquake, therefore, is of greatest concern to emergency management officials. About 3,500 dead and 14,000 injured people can be expected. Up to 45,000 people could be made homeless by the earthquake. The failure of dams in the vicinity of Ogden and Provo could add another 25,000 people to the casualty estimates and increase the homeless count to over 72,000 people. An additional 50,000 people could become homeless if tilting and subsidence allows the Great Salt Lake to move eastward.

Major earthquakes in the Wasatch Front region are expected to have large impacts on utilities and other lifelines. Electrical power may be lost over wide regions; restoration may take up to 30 days. Natural gas, water and wastewater services may be disrupted for extended periods. Damaged lines and switching equipment, plus overload traffic, will probably substantially disrupt telephone service. Major highways may be damaged due to liquefaction, fault rupture and bridge failures. Railroads and airports may be substantially damaged.

In addition to damage to infrastructure, a major earthquake may also result in fires (due to gas leaks and building failures) in residential, commercial and industrial areas (including refineries). Food supplies, food distribution, government functions, medical services and emergency services may be substantially disrupted. Hazardous materials releases and spills could add to the problems, especially if associated with fires. Evacuation of extensive areas may be required, and the loss of lifelines and blocked access to various areas will hamper emergency response efforts.

3.0 SOCIO-ECONOMIC IMPACTS OF A SEISMIC ZONE CHANGE

The scenario studies of expected earthquake damages and casualties from future earthquakes along the Wasatch Front," summarized in Chapter 2, clearly illustrate the negative impacts of major earthquakes, even though the detailed projections may only approximately indicate the extent of damage, losses, disruption, and casualties in future earthquakes. The present assessment, however, focuses not on how much damage or casualties may be caused by future earthquakes, but rather on the socioeconomic impacts of Building Code Seismic Zone changes.

The purpose of this chapter is to review the possible socioeconomic impacts which would arise specifically from a Seismic Zone change from Zone 3 to Zone 4. As discussed in Chapter 1 (Section 1.3) it is critically important to make a clear distinction between the negative impacts which seismic hazards may impose on a community and those negative impacts which may be imposed by building code seismic zonation or by changes in the seismic zonation.

3.1 What are the Differences in the Uniform Building Code Between Seismic Zone 3 and Seismic Zone 4?

Within the provisions of the Uniform Building Code (UBC) there are numerous substantial differences between the low seismic risk zones (O and 1), the moderate risk zones (2A and 2B) and the higher risk zones (3 and 4). These differences include, among others, design force levels, structural connection details, and allowable materials (e.g., whether or not unreinforced masonry is allowed in new construction).

Between Zone 3 and Zone 4, however, there is only one difference in the UBC. The design lateral force is increased by one-third in Zone 4 relative to Zone 3. In the design process, the number 0.4 is used instead of 0.3 in one computation. All other computations, details and requirements are identical in Zone 4 and in Zone 3. As a result, the effort required to design a Zone 4 building is identical to that for Zone 3.

3.2 Will the Knowledge and Capabilities of Architects, Engineers, Contractors, and Building Officials Have to Be Increased?

A change in the UBC Seismic Zone from Zone 3 to Zone 4 would require no additional professional knowledge, expertise, or capability from anyone involved in the design, construction or inspection of new buildings. Enforcement of Zone 4 requirements would require no additional effort beyond that required to enforce Zone 3 requirements.

3.3 Will the Potential Liability of Building Owners be Increased?

A change in the UBC Seismic Zone from Zone 3 to Zone 4 would have virtually no affect on the potential liability of either public or private building owners. However, liability issues are increasingly important for building owners and are often misunderstood. 'The two primary references dealing with seismic liability issues are somewhat outdated (and based on California law and experience)."-" Therefore, we briefly review the legal principles by which liability is determined.

Tort liability arises when there is a civil wrong, other than a breach of contract, for which courts may award damages. Liability is generally determined under a negligence standard, by which the reasonableness of the defendant's actions is determined. There are four elements of negligence:

DUTY,

BREACH of that duty,

CAUSATION of the event, and

DAMAGE to the complaining party.

All of these four elements must be shown by the complaining party. Therefore, there must first be a duty and then a breach of that duty before any tort liability can be incurred by building owners.

Under most circumstances, a private building owner is under a duty to follow the municipality's building codes in keeping his or her structure in a habitable and safe condition. Simply stated, this only requires the building owner to follow the codes as promulgated by the governmental entity. The burden of fact-finding and development of more stringent building codes falls on the state and local governments through their police power to protect the health and safety of its citizens. Therefore, a building owner does not breach any duty of care when he or she strictly adheres to the laws which affect their structure. In this context it is very important to note that a change in the UBC Seismic Zone from 3 to 4 would only affect new construction and would have no affect on existing buildings.

Therefore, it seems highly unlikely that private building owners would incur increased liability with a Zone 3 to Zone 4 change, unless, of courser they failed to follow any legal requirements imposed on their building. For completeness, we note that building owners in other jurisdictions have sometimes agreed to settlements in cases where damage or failure of their buildings in an earthquake resulted in deaths or injuries. It is important to note that such financial settlements, made to avoid litigation, are not a finding of guilt or liability and should not be construed to be so.

The potential liability of public-sector building owners is limited by that fact that most local governments have several statutory immunities. Many local government immunities are based on the concept of discretionary immunity. This immunity applies to basic policy decisions which have a planning, rather than operational, character. For example, a city council's decision to enact a law requiring landowners to disclose geologic and soils condition prior to selling their property or building on it would be immune as a discretionary function. A City Manager's decision to waive the requirement may or may not be immune, depending on the language of the ordinance and the factors used to make the decision. The clerk who issues a building permit without requiring the disclosure document would not be immune under the discretionary function theory. The higher the level of the decisionmaker in the governmental chain of command, the more likely that this immunity applies.

However, failure of a local government to comply with statutory or mandatory duties imposed by the state or federal governments may constitute a breach of their duty, which could result in liability in some circumstances. Such duties include aspects of:

- enforcement of building codes and standards;
- inspecting, certifying and issuing permits for projects;
- implementing environmental review; and
- planning for emergencies and disasters.

Public officials will not incur liability so long as they perform their public functions in a reasonable manner as expressed above. In addition, public entities and officials have the immunity defense as protection. Therefore, it seems extremely unlikely that public liability will increase as a result of a change from Zone 3 to Zone 4. If anything, public liability would decrease if higher standards were established in accordance with current knowledge of the seismic risk.

3.4 Impact on the Cost of New Buildings?

The impact of a Seismic Zone change from Zone 3 to Zone 4 is generally very small for new construction. The small incremental cost is due primarily to the fact that the Zone change from 3 to 4 predominantly affects the structural systems of a building. Structural systems typically only constitute about 20% of the total building cost. Therefore, modest increases in cost for the structural systems have small impacts on total building costs. Once non-structural systems are designed to resist earthquakes, the force level (Zone 3 or Zone 4) is of little consequence in determining costs.

The increased cost of designing a new building to meet the Zone 4 LTBC requirements compared to the costs of meeting Zone 3 requirements have been investigated in a recent study sponsored by the National Science Foundation." For a range of typical buildings, the increased cost ranged from practically nothing (0. 10%) to about 1.5 %. The results of this study are summarized in Table 1.

The range of increased costs shown in Table 1 reflect differences in construction types and the extent to which seismic provisions control the design. For example, wind load controlled the design of the 23 story steel frame building and thus the impact of the seismic provisions was virtually negligible. The parking garage structure example shows an unusually large cost increase, 3.37%. This extreme example reflects that fact that structural costs are a high percentage of a parking garage structure because the architectural, electrical, mechanical and other details which constitute the largest fraction of typical building costs are virtually absent from a parking garage structure. For the seven buildings in this study, the average cost increase was about 0.8%.

In California, many similar buildings have been built to Zone 3 or Zone 4 standards. Experience indicates that the typical cost difference is about I %, with most buildings being between 0.5% and 1.5%. This general experience also applies to school buildings. In California, schools have been subject to very stringent seismic design, plan checking, and construction inspection requirements since the Field Act of 1933. A California Seismic Safety Commission report 14 indicates that the earthquake requirements typically add about I % to the cost of the finished school building.

A very recent study by the Insurance Research Council" has examined the incremental costs for new single family wood frame houses to meet the seismic requirements of the National Earthquake Hazard Reduction Program guidelines. The conclusion is that the extra cost ranges from essentially zero to just under one percent of the house price. These costs are comparisons between no seismic provisions and the National Earthquake Hazard Reduction Program guidelines. These results confirm that changing from Zone 3 to Zone 4 would have little impact on the cost of new home construction.

It is important to note that designing a building to Zone 4 rather than Zone 3 UBC requirements has benefits as well as costs. Zone 4 buildings have a 33% increase in their basic elastic strength (the buildings ability to withstand damaging earthquake forces without structural elements yielding and causing building failure or collapse) over Zone 3 buildings and at least a 50% increase in ultimate non-linear capacity . For moderate to high seismic risk areas (Zone 3 or Zone 4) experience with benefit/cost analysis of seismic enhancements 16 suggests that the benefit/cost ratios for such buildings would be far greater than one. Benefit/cost ratios greater than one mean that the costs are low relative to the expected future benefits (avoided damage and losses in future earthquakes) from building to a higher requirement. Benefits which accrue include lower building damages, lower content damages, reduced loss of building function, and reduced casualties. In other words, the reduced losses expected in future earthquakes outweigh the extra initial costs.

To put seismic cost in perspective, it is useful to note that the extra building costs associated with code requirements for disabled access, fire safety (e.g., required sprinkler systems) and environmental concerns (e.g., asbestos) far outweigh the change in cost that would result from instituting the structural strength increase required by Seismic Zone 4 compared to Zone 3.

Table I

NEW BUILDING COSTS: SEISMIC ZONE 4 vs. ZONE 3

NATIONAL SCIENCE FOUNDATION STUDY

BUILDING NUMBER	DESCRIPTION	AREA (sq.ft.)	PERCENT COST INCREASE	$/SQ.FT. COST INCREASE
1.	One story warehouse	87,360	0.42	$0.03

2.	**Two story wood frame 16-plex**	**6,400**	**0.38**	**0.28**
3.	**Four story concentrically braced steel frame**	**58,359**	**1.21**	**0.89**
4.	**Six story steel frame with concrete shear walls**	**101,335**	**1.14**	**0.37**
5.	**Six story concrete frame with concrete shear walls**	**116,000**	**1.48**	**0.78**
6.	**Three story parking garage ductile concrete moment frame**	**945,216**	**3.37**[2]	**0.87**
7.	**Twenty-three story steel special moment frame**	**420,000**	**0.10**	**0.05**

1. Total construction cost, excluding land, interest, professional fees.

2. This is not a typical building, because it is primarily structural.

3.5 Impact on the Change of Use, Renovation or Rehabilitation of Existing Buildings?

Neither the Uniform Building Code (UBC) nor either of the other two major model building codes in common use in the United States requires the seismic retrofit of existing hazardous buildings if there is no change of use. Under most circumstances, therefore, a UBC Seismic Zone change from Zone 3 to Zone 4 has virtually no impact on the change of use, renovation or rehabilitation of existing buildings. Under Section 502 of the UBC, however, if a renovation also involves a change of use which is not less hazardous, based on life safety and fire risk, then the building may be made to conform with current code for the new occupancy. The implication in this section is that the local building official has the discretion to determine which use is less hazardous and thus may or may not require that the building, including its structural elements, conform to current code. Whether or not this somewhat vague code provision is invoked in particular situations varies from jurisdiction to jurisdiction.

The Uniform Code of Building Conservation (UCBC) is a companion code to the UBC which jurisdictions may or may not adopt in addition to adopting the UBC. In Utah, the UBC is adopted state wide. The Uniform Building Code Commission of the State of Utah has recommended that local jurisdictions adopt the UCBC, but such adoption is not mandatory. To date, very few jurisdictions have chosen to adopt the UCBC. However, since the UCBC does affect some seismic rehabilitation’s, its provisions are briefly reviewed below.

The seismic rehabilitation provisions of the UCBC deal with unreinforced load-bearing masonry construction. The requirements of the UCBC produce buildings better able to resist small to moderate earthquake forces. However, large magnitude earthquakes may still cause heavy damage or collapse of such buildings. The UCBC provides a set of requirements which are a minimum for the improvement of such buildings when they are to be strengthened. These provisions may apply when the use of the building is changed to one that would put more people at risk or when the building is to house a more important function. However, local jurisdictions may adopt the structural provisions of this code, while adopting local administrative provisions for determining the circumstances under which the strengthening requirements are triggered.

The impact of a change from Seismic Zone 3 to Zone 4 would have some impact on rehabilitation costs under the UCBC provisions. The base shear (lateral force) requirement would be increased by one-third. This increase in design force level would have little effect on the two most important strengthening actions for unreinforced masonry buildings: 1) parapet wall bracing and 2) diaphragm (i.e., floors and roofs) anchoring to walls. For those vulnerable, weak buildings where the Zone 3 requirements require strengthening the masonry walls for in-plane forces, the seismic zone change would have little impact. Once it is required to strengthen the walls, the increased cost to perform this task to a slightly higher force level usually is not significant. For buildings, that would not require wall-strengthening in Zone 3, but would in Zone 4, the extra cost would be significant.

In most cases, where the UCBC provisions are not in place, or for buildings other than unreinforced load bearing masonry, the Seismic Zone 4 designation would not have a direct impact on rehabilitation techniques or costs. The situation would be the same as it is currently; namely, since most jurisdictions have no seismic rehabilitation requirements, there would be no change. For the few jurisdictions that do have design force level requirements for seismic rehabilitations, local officials are free to set the force value at a level they feel is appropriate.

To date, virtually all seismic retrofitting which has occurred in Utah has been on a voluntary basis. Since the work is voluntary, the owner is generally free to choose whatever level of earthquake performance that is desired. In some cases, the owner may negotiate with local building officials to determine an acceptable level of seismic retrofitting.

As discussed above, a UBC Seismic Zone change would have virtually no effect on renovation or rehabilitation of existing buildings, except in some circumstances under changes of use. Nevertheless, the cost of seismically retrofitting existing buildings is an important issue for building owners and an important public policy issue. Seismic retrofit of hazardous buildings is also important from a life safety perspective as well as from a financial perspective.

The seismic retrofit of existing buildings can be expensive, with typical direct costs ranging from a few dollars per square foot to as much as $30 per square foot. 16-17 Total costs including possible relocation during construction and other non-engineering costs can also add considerably to the total retrofit cost. In considering the cost of seismically strengthening a building, however, it is important to separate those costs which are properly attributed to the seismic retrofit from other rehabilitation costs which may improve the building but which are not required to seismically strengthen the building. A recent Federal Emergency Management Agency (FEMA) publication" has reviewed both the benefits and costs of seismic rehabilitation of buildings.

Unless required by other levels of government, local jurisdictions may, at their discretion, adopt retrofit ordinances which may mandate, under certain conditions, the seismic retrofit of existing buildings. The local, political decision about whether or not to adopt a retrofit ordinance and the determination of under what conditions retrofit may be mandatory is completely separate from the question of seismic zonation. Increased perception of seismic risk (objective or perceived) may lead to seismic zone increases and to retrofit ordinances. However, a seismic zone increase does not obligate a local jurisdiction to adopt a retrofit ordinance.

In California, where the frequency of damaging earthquakes is higher than in Utah, and public awareness of seismic risk is correspondingly higher, relatively few local jurisdictions have adopted mandatory retrofit ordinances. Where adopted (for example, Los Angeles), retrofit ordinances generally apply only to unreinforced masonry buildings. Only a handful of jurisdictions have applied mandatory retrofit requirements to buildings other than unreinforced masonry.

A few retrofit ordinances apply to all structures of a given class. For example, Los Angeles required the strengthening (or demolition) of all unreinforced masonry buildings (other than one- or two-family homes) within a ten year period. Retrofit ordinances which only require retrofit when specified 'trigger" actions are met are much more common. A recent review of seismic retrofit policies" discusses the common types of triggers. Triggers may be "active," that is, based on hazardous conditions such as parapets or earthquake damage, or "passive," that is, based on change of use, major remodel, substantial structural alterations, vacancy, or change of ownership.

3.6 Impact on the Value of Existing Buildings?

The impact of a Seismic Zone change from Zone 3 to Zone 4 on the value of existing buildings is probably negligible. The most populated areas of both California and Alaska have had increases from Zone 3 to Zone 4 since the mid-1980's. There has been no known effect on the resale of existing buildings which were built before the zone change for these two states. Furthermore, the UBC itself has changed markedly over the years. In some cases, the UBC changes within a Seismic Zone have been greater than the current difference between Zone 3 and Zone 4. There appears to be no evidence that these UBC changes affect the values of existing buildings.

Existing buildings generally have lower values than do recently-constructed buildings. This difference in value is attributable to changing styles and functional requirements as well as to the gradual deterioration which affects older buildings. The affect of perceived seismic risk (which is largely separate from Seismic Zone issues) generally has only a limited impact on a building's desirability, rentability, or value.

There are, however, exceptions to the above generalizations. Building types that are perceived to be very hazardous may suffer considerable loss-of market value. For example, in California; much attention has been focused on the seismic vulnerability of unreinforced masonry buildings. In San Francisco, where several unreinforced masonry buildings suffered heavy damage in the Loma Prieta earthquake, the city is currently considering a mandatory retrofit ordinance for unreinforced masonry buildings. Such buildings have become quite unmarketable.

The reduced value of unreinforced masonry buildings, as described above, has a great deal to do with objective and perceived seismic risk and free market conditions. It has little to do with UBC Seismic Zonation per se. Furthermore, a California study found that retrofitted unreinforced masonry buildings sold at a premium over non-retrofitted buildings. This confirms that, perceived seismic resistance is valued by the real estate market.

It is very important to note that in most cases, factors other than perceived seismic risk predominantly determine the value of an existing building (e.g., location, amenities, etc.). A major study has been conducted on the impact of earthquake risk on California's housing and rental markets." More than one million residential real estate transactions were analyzed to determine the possible effects of perceived seismic risk on resale value. In California, areas which are subject to surface fault rupture (immediately in active fault zones) are designated as Alquist-Priolo Special Studies Zones. The sales price of properties located in such extremely hazardous Zones is no different than for properties located outside such zones. This conclusion held for every year from 1977 to 1990 and for locations in both northern and southern California.

3.7 Impact on the Value of New Buildings?

As discussed above for existing buildings, perceived seismic risk is generally negligible in determining the value of buildings. For new buildings, factors such as location and amenities will certainly predominantly determine a building's value.

New buildings designed to higher standards than most buildings in a city may attract some tenants who are particularly seismic-risk adverse. Seismic-risk adverse tenants may be those who place a high value on life-safety or those whose business functions would be severely impacted by seismic damage or disruption. Therefore, the perceived seismic performance levels of new buildings may have a slightly positive impact, although the studies on existing building values certainly suggest that any such positive impacts would be very small.

3.8 Impact on Residential Earthquake Insurance?

Earthquake insurance differs from most other types of insurance because rates are not actuarially set; that is, rates are not based directly on previous loss experience. Rather, earthquake insurance rates are sometimes based roughly on probabilistic estimates of expected losses and sometimes based simply on what the market will bear. In many cases, rates are higher than justified on actuarial grounds, to compensate for the possibility of catastrophic losses in infrequent but very damaging earthquakes (what is known as the "probable maximum loss" in the industry). Several recent reports provide a general overview of earthquake insurance issues.'0-2'

In general, insurers are reluctant to write earthquake insurance because of the possibility of huge losses in the event of a catastrophic earthquake, because of the difficulty in assessing proper premiums, and because of a fear of adverse selection. Adverse selection occurs when a disproportionately high fraction of people in the highest risk (because of location or building vulnerability) choose to obtain earthquake insurance.

In Utah, residential earthquake insurance is currently sold as an endorsement on a standard comprehensive homeowner's policy or as part of a stand-alone catastrophe insurance policy. Earthquake insurance rates are based on a-number of factors -- frequency of earthquakes and population (risk zone), structure (frame, brick veneer, brick), and value of the home. Utah earthquake insurance zones are shown in Figure 3. Minimum deductibles are 5, 10, or 15 percent, depending on the type of construction.

Catastrophe insurance covers all risks of physical damage from any external cause, including earthquake and flood, excluding perils which are covered in Section I of a Standard Homeowner's Policy, Form 3. Stand-alone catastrophe insurance policies are based only on the value of the home; current rates are approximately $3.00 to $4.00 per year per $1000 of home value. The deductible is 2.5 percent.

In Utah, the majority of all residential earthquake insurance written is sold to owners of property along the Wasatch Front (because of the concentration of population and the higher perceived risk in this region). If the Wasatch Front region is reclassified as Seismic Zone 4, insurers may (or may not) choose to increase rates. Based on higher perceived risk, insurers could increase rates. On the other hand, as newer houses built to Zone 4 (or Zone 3) constitute an increasing fraction of the total residential building stock in Utah, the seismic vulnerability of the stock as a whole would be gradually reduced. Therefore, the risk to insurers would gradually decrease and rates might be reduced.

To investigate possible differences in earthquake insurance rates between Zone 4 and Zone 3, we review California data. Earthquake insurance rates vary markedly as a function of deductible, with lower deductible policies being much more expensive than higher deductible policies. In California, residential earthquake insurance is typically sold with 10 percent deducible. Table 2 shows residential earthquake insurance rates in California for 22 companies, for wood frame dwellings in San Francisco (Zone 4) and Sacramento (Zone 3), as well as masonry dwellings in San Francisco. Rates vary substantially from one company to another.

For wood frame houses in Zone 4, the average rate is $2.19 per $ 1 000 with a low rate of $1.27 and a high rate of $4.30. For masonry houses in Zone 4, the average rate is $12.82 per $1000, with a low rate of $6.00 and a high rate of $26.98. For wood frame houses in Zone 3, the average rate is $1.36 per $1000, with a low rate of $0.50 and a high rate of $2.27. On average, Zone 4 rates for masonry are 5.60 times higher than for wood frame houses. Zone 4 rates for wood frame houses average 1.68 times higher than in Zone 3.

Table 2

EARTHQUAKE INSURANCE RATES:

ZONE 3 VS. ZONE 4 (CALIFORNIA)[1]

Zone 3 (Sacramento, Zip Code 95826) and Zone 4 (San Francisco Zip 94109)

Annual Rates for Dwellings per $1000 of Coverage with 10% Deductible

Insurance Company	San Francisco FRAME $ rate/1000	San Francisco MASONRY $ rate/1000	Sacramento FRAME $ rate/1000	San Francisco MASONRY/ FRAME[2]	San Francisco/ Sacramento FRAME[3]
1	$2.27	$9.83	$2.27	4.33	1.00
2	$1.50	$6.00	$0.70	4.00	2.14
3	$2.60	$15.60	$1.60	6.00	1.63
4	$4.00	$20.00	$3.00	5.00	1.33
5	$2.00	$8.00	$1.00	4.00	2.00
6	$2.00	$10.00	$2.00	5.00	1.00
7	$2.30	$8.90	$2.10	3.87	1.10
8	$2.05	$12.89	$1.03	6.29	1.99
9	$1.56	$8.07	$1.25	5.17	1.25
10	$2.50	$17.50	$0.50	7.00	5.00
11	$1.27	$6.40	$0.91	5.04	1.40
12	$2.00	$12.55	$1.10	6.28	1.82
13	$2.51	$5.03	$1.01	2.00	2.49
14	$2.15	$13.49	$1.08	6.27	1.99
15	$3.23	$20.24	$1.62	6.27	1.99

16	$1.50	$6.00	$0.70	4.00	2.14
17	$4.30	$26.98	$1.80	6.27	2.39
18	$1.80	$12.14	$0.97	6.74	1.86
19	$2.50	$17.00	$1.00	6.80	2.50
20	$2.15	$13.49	$1.08	6.27	1.99
21	$1.94	$12.82	$1.94	6.61	1.00
22	$2.30	$19.21	$1.15	8.35	2.00
AVERA	**$2.29**	**$12.82**	**$1.36**	**5.60**	**1.68**

1. California Department of Insurance, Statistical Analysis Bureau, October 16, 1992.

2. Ratio of rates for San Francisco Masonry Dwellings vs. Frame Dwellings.

3. Ratio of rates for Frame Dwellings in San Francisco vs. Frame Dwellings in Sacramento.

3.9 Impact on Commercial Earthquake Insurance Rates?

Many of the comments about residential earthquake insurance also apply to commercial earthquake insurance. There are, however, some important differences. Commercial earthquake insurance rates vary more depending on the type of business and the degree of exposure to loss estimated by the insurer. Some insurers conduct detailed analyses of particular companies and sites before setting rates; such companies often assume much of the risk and pass on relatively little to reinsurers. Other companies make far fewer site-specific risk investigations; such companies tend to pass most of their exposure on to reinsurers.

As with residential insurance, most commercial earthquake insurance is not based actuarially, but is rather based on a rough estimate of risk and/or on whatever the market will bear. Whether or not a seismic zone increase from 3 to 4 would significantly impact commercial earthquake insurance rates is difficult to predict. The Insurance Services Offices guidelines indicate rates for Zone 3 which are about one-half of those for Zone 4. However, in practice few companies appear to follow these guidelines.

4.0 SUMMARY AND CONCLUSIONS

The proposed Uniform Building Code Seismic Zone change from Zone 3 to Zone 4 generated a great deal of spirited debate among both proponents and opponents of the change. Claims and counterclaims were made. Local newspapers carried numerous articles about the issue. In February 1992, the International Conference of Building Officials' committee responsible for seismic zone changes disapproved the requested change.

The zone change issue continues to be important because both proponents and opponents of the zone change continue to believe that their position is correct.

4.1 What are the Subjective and Objective Attitudes of People Who May be Impacted by the Zone Change?

Virtually all of the people who became publicly involved in the debate over the prospective seismic zone change were professionals involved in the field (architects, engineers, building officials) or business people who felt that their business interests would be substantially impacted by a zone change (property owners, developers, real estate people, construction industry people). Relatively little was heard from ordinary citizens during the debate.

Proponents of the zone change gave credibility to the reports from the Utah Geologic Survey and the United States Geologic Survey which supported the zone change proposal. Many opponents believe that these geologic studies overstate the risk or prefer older studies which reached different conclusions as to the recurrence interval of earthquakes large enough to exceed the UBC Zone 4 criteria. Opponents also repeatedly make comparison between the perceived seismic risk in Utah and that in California. As frequently mentioned in newspaper articles, opponents stated that the zone change would place Utah in the same Seismic Zone as the most seismically active portions of California. Opponents viewed Utah being in the same seismic zone as California as unfair, while proponents believed that a higher seismic zone for Utah would provide improved protection for life and property.

The perceived costs of making a seismic zone change- were considered by both proponents and opponents. Proponents believed that costs were relatively modest and well worth the added margin of safety. Opponents consistently believed that the costs of the change would be much higher than stated by proponents. Opponents believed that the added costs were not justified by the added margin of safety.

4.2 What Would be the overall Economic Impact on Development and the Housing Trades, Including Architects, Engineers, Developers, Realtors, and the Construction Trades?

The direct impact of a seismic zone change from Zone 3 to Zone 4 on building professionals (architects, engineers, and building officials) is negligible. As discussed in Chapter 3, such a seismic zone change only changes one number in one calculation and thus has no impact on the professional skills or effort required of building professionals.

The question of what the overall economic impact on the community would be is somewhat more difficult to answer. Increasing the seismic zone to Zone 4 would add very slightly to the cost of new construction, typically I % or so. It is difficult to believe that such a small change would have a significant economic impact; the change is small compared to changes imposed by interest rate changes and business cycle changes. Therefore, it appears highly unlikely that the seismic zone change would impact negatively on new construction or development.

The economic impact on existing buildings would probably be extremely small, based on the California experience, with the exception of buildings such as unreinforced masonry buildings which might be perceived as particularly hazardous. In this case, the desirability and value of such buildings might be significantly impacted. It is important to note, however, that such impacts are primarily determined by objective and perceived risk and thus have very little to do directly with a seismic zone change.

Overall, the economic impact of the prospective seismic zone change would probably be extremely small. Most possible negative impacts arise primarily from perceived or objective seismic risk and only marginally arise from building code seismic zonation. Factors other than seismic risk or building code zones predominantly determine the economic well being of a community. Finally, it is important to remember that increasing the seismic zone from Zone 3 to Zone 4 has benefits as well as costs - better building performance in future earthquakes with greater protection of both life and property. Better building performance would also result in less disruption of both private and public section functions in future earthquakes and help to accelerate post-earthquake recovery. Ultimately, however, the decision about whether or not the benefits of increasing-the seismic zone from Zone 3 to Zone 4 remains a local, political decision to be made by the citizens of Utah.

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